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SCALE, SIZE, TECHNOLOGY AND STRUCTURE:

A PERSONAL PERSPECTIVE

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In these notes I first discuss some recent perspectives on the relationship between technical change and economies of scale. I then discuss the issues of scale economies from the perspective of the Hayami-Ruttan work on induced innovation. In the third section I raise the question of why farms are so small. I then turn to the issue of potential technological constraints on labor and land productivity. In a final section I raise several questions about research on farm structure.

I

Discussions of technical change, economies of scale and farm size are burdened with a rhetoric that makes effective communication exceedingly difficult. In much popular and even professional discussion it is taken as self-evident that the historical association between advances in mechanical technology, growth in labor productivity and increases in farm size can be taken as evidence of scale economies (OTA, 1986). In this view technical change has led to size or scale economies, a reduction in farm numbers and the exit of labor from agriculture. An implication that is sometimes drawn is that the appropriate policy is to slow the role of technical change.

But changes in farm size may also be due, at least in part, to changes in relative factor prices--to the long-run increase in the price of labor relative to other factors. There is a body of literature that suggests that almost all increases in farm size can be accounted for by factor substitution along a neo-classical production function. According to Peterson and Kislev "the ratio of the opportunity cost of farm labor to the price of machinery services determines the size of the farm operation by influencing the machinery-labor ratio... We explain virtually all of the growth in the machine-labor ratio and in farm size over the 1930-70 period by changes in relative factor prices without reference to 'technological change' or 'economies of scale'" (Kislev and Peterson, 1981; Kislev and Peterson, 1982). If this view is correct the fact that real wages in manufacturing have now remained stable for approximately a decade and a half would account, at least in part, for recent farm size stabilization.

There is also an emerging body of literature that has attempted to formalize and test the insights of Allyn Young (1928) which attribute much of firm growth to external scale economies (Romer, 1986; Romer 1987). In Romer's work it is the emergence of an increasingly complex or differentiated set of specialized inputs and the spillover of knowledge between firms that is the source of externality. My guess is that the Romer effects would become increasingly important in the agricultural sector as the level of purchased inputs, capital and operating expenses rises relative to inputs supplied by the individual farm. Evidence that very large farms acquire inputs at lower cost or receive higher prices for their product than most farms is consistent with this hypothesis (Miller, 1979).

II

Work I have conducted with Yujiro Hayami, Hans Binswanger and others, treats the direction of technical change, measured by change in partial productivity ratios, as induced by changes in relative factor prices which, in turn, reflect underlying changes in resource endowments. I have been somewhat less comfortable with the use of the Schmookler-Griliches demand induced technical change model in interpreting the rate of technical change. The rapid rate of technical change in agriculture, as measured by growth in output per unit of total input, in the presence of slow growth in demand, suggests that a richer explanation is needed to understand the rate of technical change.

Observed scale economies in agriculture are, in my view, primarily a reflection of disequilibrium associated with lags in the adoption of new technology. Let me illustrate from the recent cross-country production function estimates by Kawagoe, Hayami and Ruttan (1985) and Hayami and Ruttan, (1985, pp. 138-160). These results suggest the presence of economies of scale in developed country agriculture and lack of economies of scale in developing country agriculture over the 1960-1980 period.

Results of a reestimation by Kislev and Peterson, using country dummies, did not find scale economies (Kislev and Peterson, 1986). A more recent re-estimation by Lau and Yotopoulos (1987) using transformed first differences, individual country dummies and a transcendental logarithmic specification finds that returns to scale are positively related to levels of machinery input per farm. Their findings indicate, like those of Hayami and Ruttan, that most LDC's are operating in the region of constant returns to scale and most DC's are operating in the region of increasing returns.[1]

We interpret these results as reflecting the rapid, though incomplete, introduction and adoption of mechanical technology in the developed economies. These mechanical technologies tend to require somewhat lumpy or discrete adjustments in factor-factor ratios at the farm level. In the developing countries, in contrast, the technical changes which were occurring during 1960-1980 were primarily biological and chemical. These technologies were highly divisible and were adopted with little lag between introduction and adoption.

Glenn Johnson had tended to be more than somewhat critical of both our methodology and the interpretations (Johnson, 1984). He has been particularly offended by the weakness of our micro-economic analysis. Furthermore, reanalysis of several micro-economic studies suggests less support for the presence of economies of scale than had earlier been assumed (Hoch, 1976). Nevertheless, it seems quite apparent to me that a micro-economic analysis, based on a sample of firms during a period of rapid advance in mechanical technology, could be expected to find evidence of economies of scale that reflect disequilibrium in factor-factor and factor-product price and use ratios. This view is confirmed in recent studies using individual farm data such as that by Kuroda (1987). Kuroda found that in post-war Japan economies of scale emerged during two periods

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[1]The Lau-Yotopoulos re-estimation also finds larger coefficients for land and fertilizer and lower coefficients for machinery and education than Kawagoe, Hayami and Ruttan. In the Lau-Yotopoulos model the country dummies apparently pick up the intercountry effects of differences in general and technical education plus differences in the country specific factors such as soils, climate and infrastructure.

of rapid mechanization. The first period, the late 1950s and early 1960s, was associated with rapid increases in small-size machinery. The second, the early 1970s, was characterized by the even more rapid introduction of larger-size machinery.

III

Let me now turn to one of the issues that I would like to see researchers in farm management and production economics confront more directly. There has been, as noted above, a great deal of literature on why farms have become larger. But even larger farms are quite small in comparison with large firms in other sectors of the economy. The interesting question, for which an intellectually satisfactory answer is not yet available, is why farms are so small.

One aspect of this issue is the size of the operating unit. A response to this question is offered in John Brewster's classic, but neglected, article on "The Machine Process in Agriculture and Industry" (1950). Brewster argues that a major difference between the use of mechanical technology in industry and agriculture is that in industry men and machines remain stationary while the materials are mobile; in agriculture the materials are stationary while the men and machines must be mobile.[2] The effect of mechanization in agriculture is to spread men

[2]"In pre-machine times, farming and manufacturing were alike in that operations in both cases were normally done sequentially, one after another; usually by the same individual or family. The rise of the machine process has forced agriculture and industry to become progressively different in respect to the sequence in which men once performed both farm and industrial operations. For in substituting machine for hand power and manipulations in agriculture, individuals in no wise disturb their pre-machine habit of doing their production steps one after another whereas in making the same substitution in industry men thereby force themselves to

across even larger areas and thus enhance the problem of supervision. In industry the effect was to concentrate workers in less space and hence increase the number of workers that could be supervised by one manager. A second consequence of the differential pattern of mechanization is that the annual cycle of activity in crop agriculture requires a sequence of specialized machines, each of which is used for a relatively few days per year. The effect is that a fully mechanized agricultural system tends to be much more capital intensive than a fully mechanized industrial system.

A second issue that needs more careful analysis is the effect of risk on farm size. It seems reasonable to hypothesize that the optimal size of the operating unit will be smaller in an environment characterized by high risk, arising from either natural or institutional sources, than in an environment characterized by lower risk. I was surprised, in spite of the recent upsurge of literature on the impact of risk on farm decision making, to find that the issue of the impact of risk on farm size has apparently been completely neglected.

The fact that span of control and risk may limit the size of the farm operating unit is not sufficient to answer the question of what limits the size of the ownership unit. Why do we not see many more large ownership units in which the individual "divisions" are operating units managed by a hired manager, a tenant, or a limited partner? It may be useful to go to

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acquire increasingly new habits of performing simultaneously many operations in the production process. As a consequence, the 'Industrial Revolution' in agriculture is merely a spectacular change in the implements of production whereas in industry it is a further revolution in the sequencing (order) in which men use their implements" (Brewster, 1950, pp. 69,70).

the literature on the "agency problem" and "transaction costs" to search for an answer (Williamson, 1967; Grossman and Hart, 1986; Stiglitz, 1974). It simply may not be possible to construct contractual arrangements which are incentive compatible. In a situation where there is a potential surplus, over and above factor costs, to be divided between the owner and agent, it may not be possible to write contracts which simultaneously solve the dilemma of incentives for efficiency and the moral hazard problem.

IV

I would now like to turn to some of the implication of technical change for changes in factor proportions and farm structure. In Figures 1 and 2 we have traced recent and longer-run trends in land and labor productivity and in land/labor ratios for a number of developed and developing countries. The interesting question is where will these trends take us over the next several decades?

The perspective on the possibilities of change have shifted dramatically over the last decade. The mid and late 1970s could be characterized as a period of considerable pessimism regarding the capacity of agricultural technology to offset the effects of resource constraints. During the 1980s the potential impact of the new biotechnologies has resulted in considerable euphoria about the prospects for technical change and to the expectation that agricultural commodity prices will remain depressed into the foreseeable future. The fear of scarcity has been replaced by a fear of abundance.

There has been a great deal of speculation to the effect, as a result of advances in biological technology associated with the new knowledge in molecular biology and its applications, that American agriculture may be confronted with a new burst of productivity growth that will substantially exceed the rate of growth in demand for agricultural commodities. It is anticipated that advances in animal health and animal productivity will come first, followed by advances in plant protection and somewhat later by advances in plant productivity. But I see nothing in the evidence presented in the recent rash of technology assessment studies[3] that leads me to anticipate productivity gains over the next several decades comparable to the gains achieved since 1940 as a result of (a) the reduction in farm labor and work-animal inputs associated with advances in mechanical technology and (b) the increases in crop yields and animal feeding efficiency resulting from advances in plant and animal breeding and in crop and animal nutrition.

We can expect a slowing of additional gains from advances in mechanical technology. It appears to me that the cost of saving an additional man-day by adding more horse-power per worker has largely played itself out in countries like the United States, Canada and Australia. Modest gains in firm level efficiency and sector level productivity may still occur as a result of further changes in farm structure (Edwards, 1985; Cooke and Sundquist, 1987). It is, however, time to stop talking as if adjustments in farm size and farm structure or reductions in labor input per hectare, have very much to contribute to either efficiency in agricultural production or to intersector equity in income distribution in the United States.

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[3]See for example the section on "Emerging Technologies for Agriculture" in OTA (1986) and Charles Benbrook, Dale Jorgenson, Ralph Landau and Vernon Ruttan, eds. (1988).

I am also less optimistic than I have been in the past about the prospects for continued high rates of growth in output per hectare. Increases in crop yields by crop breeders during the last half century breeding have been achieved primarily by selection for a higher harvest index--by redistributing the dry matter between the vegetative and reproductive parts of the plant (Jain, 1986). The harvest index has risen from the 20-30 per cent range to upward of 50 per cent for several major grain crops. There is growing concern that a plateau is now being reached in yield potential based on failure, under experimental conditions, to push the harvest index much above 50 per cent. If this is correct, it means that future gains in those countries that are currently pushing against the technological frontier will have to come from increases in total dry matter production resulting from enhanced photosynthetic capacity. And the biological basis for such advances has apparently not yet been established.

If we can turn again to Figures 1 and 2, it is not apparent whether the countries in the upper left quadrant (such as Japan) and the countries in the lower right quadrant (such as the United States) are moving toward higher land and labor productivity along parallel or convergent paths. If we were moving along convergent paths the long run prospect would be for comparable land-labor ratios in farming across countries. At present, however, there does not appear to be any strong tendency toward convergence.

V

Let me now turn to some questions about why the issue of farm or structure is on the research agenda. First let me address three reasons that are often advanced.

One reason that is sometimes advanced is the fear that farm structure may become so concentrated that organized producers may be able to extract excessively high prices from consumers. I myself see no reason why consumers should be concerned about this issue. The commodity component of food costs is relatively small and, for those few specialized commodities (lettuce, carrots) where production has, or is likely to be, highly concentrated the elasticity of substitution in consumption is reasonable high. If consumers are worried about price effects, they should take a more active role in deregulating agricultural production and rethinking price and income supports.

A second reason that is often offered is that an agricultural system organized around small operating units has a more positive impact on the economic health of rural communities. The classic studies by Goldschmidt (1946) of Arvin and Dinuba in California are frequently cited to this effect. A recent restudy (Hays and Olmstead, 1984) casts considerable doubt on some of the inferences that have been drawn from the earlier study. However, a more fundamental basis for questioning this reason is that it is too late. The number of operating farms is too small to sustain the physical and institutional infrastructure that now exists in most rural areas. Even if there should be no further erosion of farm numbers or increases in farm size we could expect continued stress on the viability of rural communities that are primarily dependent on agriculture.

A third reason for studying agricultural structure is that it is on the populist political agenda. I would like to think that the populist concerns could be used to redirect agricultural policy in a way that would contribute to greater equity in rural areas--such as the delinking of commodity price and income supports. But it has instead been directed to the support of higher price supports and more severe acreage restrictions. The policies supported by the rural populists would have a negative impact on the competitive position of US agricultural commodities in a global markets and would contribute to the worsening of the income distribution in rural areas.

There are a number of reasons why a group such as NC-181 might find it useful to study the changing structure of American agriculture. But unless the purpose of structure studies are clearly identified, the output of the research effort is unlikely to become an input into the resolution of relevant problems. The two objectives suggested below are certainly not exhaustive.

One would be to contribute to the formulation of extension policy. The extension service is being asked to direct its energies to a wider number of clients. I anticipate that the state extension services will be the object of mounting criticism by both traditional and new constituencies over the next decade. One objective of structure studies could be to more clearly identify the clientele and the demand for the extension service in the areas of commercial agriculture, environmental quality and rural governance and development and other areas.

A second objective would be to provide state and local government with the information that they will need to modify their activities to meet the demand and the fiscal capacities of rural areas. Economic and demographic changes in rural areas can be expected to result in a decline in the demand for some services and a rise in the demand for other services. These changes will influence the capacity of governments to provide services.

If I am correct, then farm size and structure studies should be designed to respond more specifically to the information needs of state and local governance institutions and program managers.

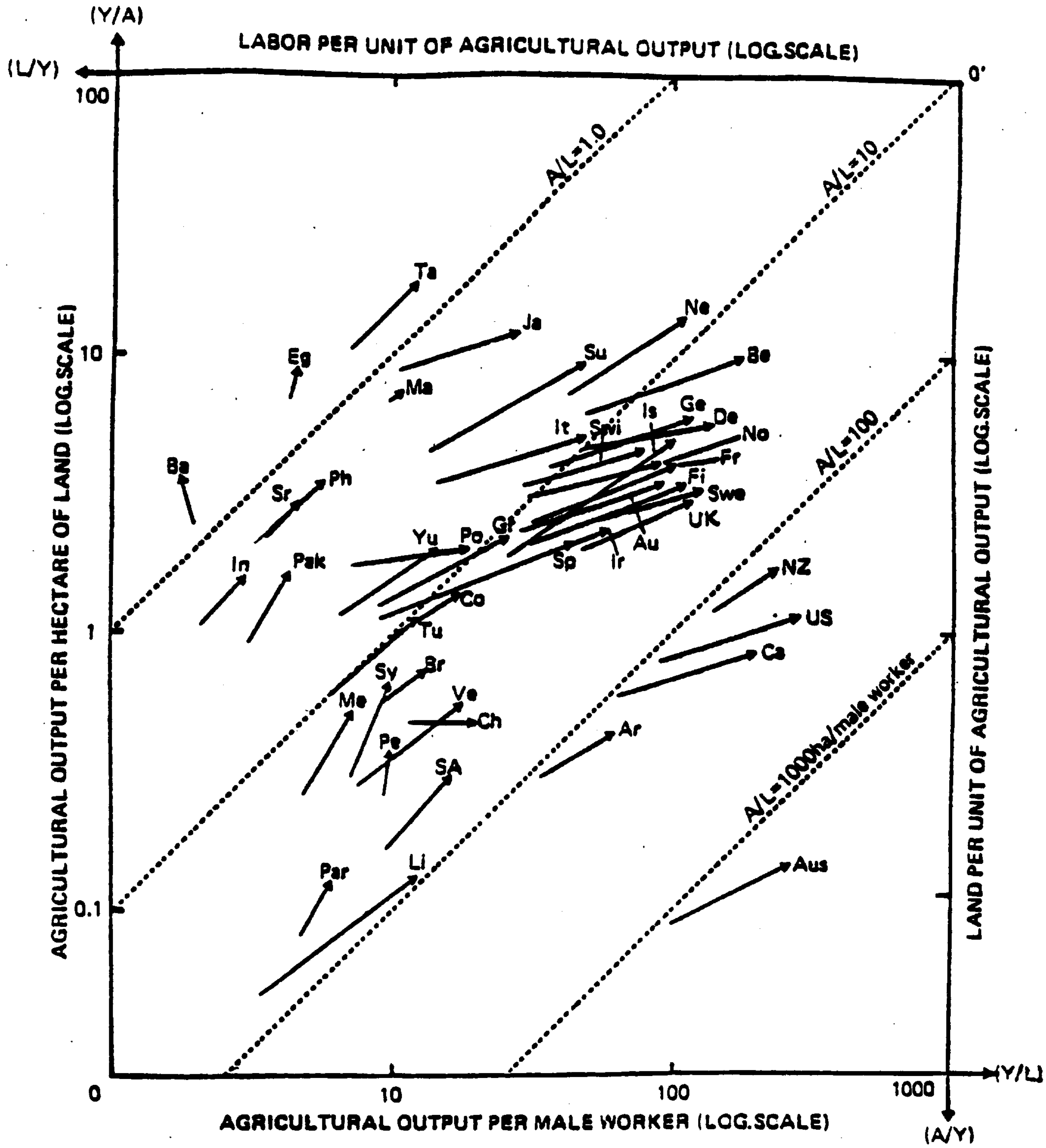

Figure 1. International comparison of labor and land productivities in agriculture: 1960–1980.

Source: Yujiro Hayami and Vernon W. Ruttan, Agricultural Development: An International Perspective, rev. ed. (Baltimore: Johns Hopkins University Press, 1985, Chapter 5.

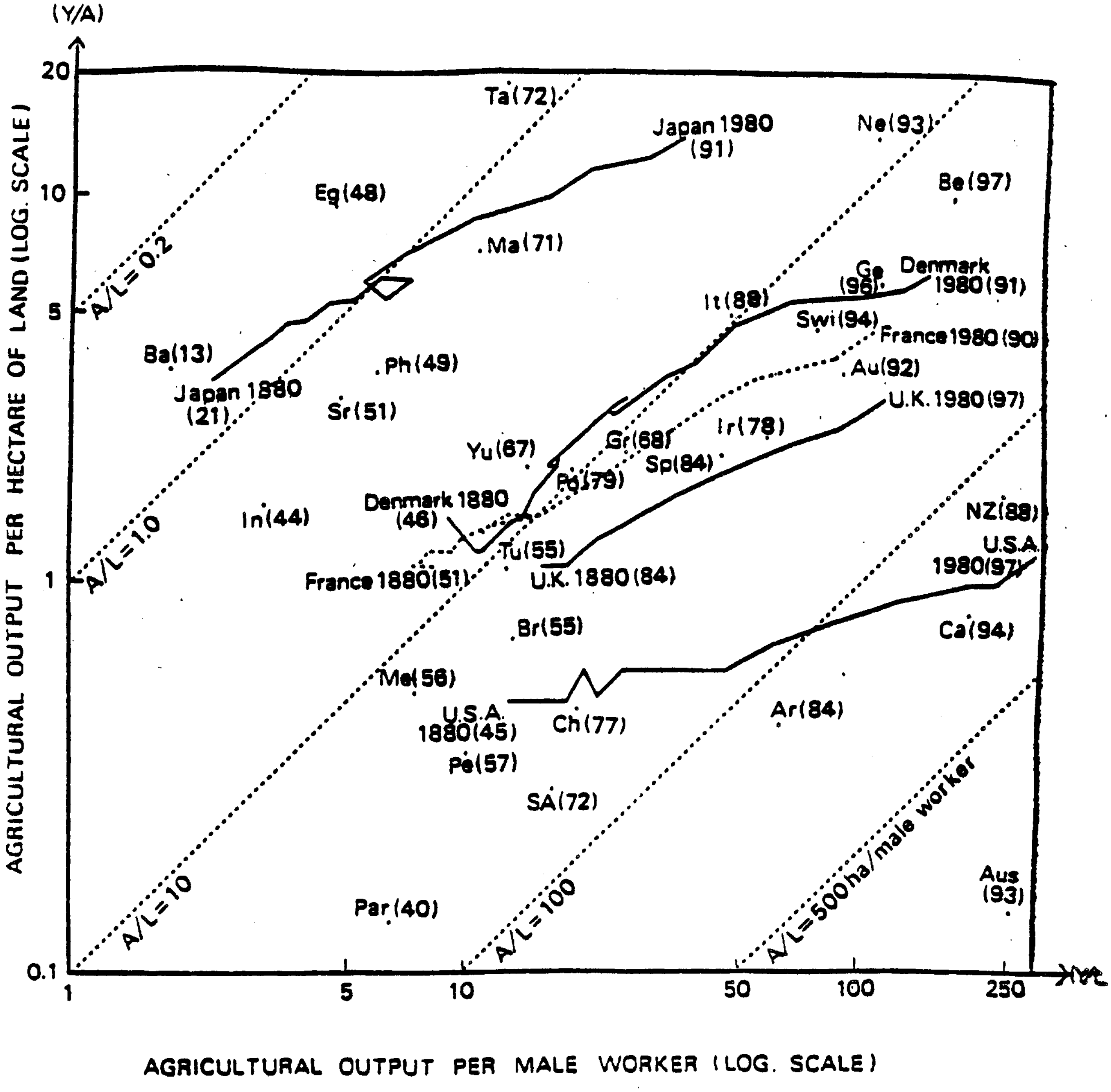

Figure 2. Historical growth paths of agricultural productivity of Denmark, France, Japan, the United Kingdom, and the United States for 1880–1980 compared with intercountry cross-section observations of selected countries in 1980

Source: Yujiro Hayami and Vernon W. Ruttan, Agricultural Development: An International Perspective, rev. ed. (Baltimore: Johns Hopkins University Press, 1985), Chapter 5.

Symbol key for Figures 1 and 2

Argentina	Ar	Norway	No
Australia	Aus	Pakistan	Pak
Austria	Au	Paraguay	Par
Bangladesh	Ba	Peru	Pe
Belgium (& Luxemburg)	Be	Philippines	Ph
Brazil	Br	Portugal	Po
Canada	Ca	South Africa	SA
Chile	Ch	Spain	Sp
Colombia	Co	Sri Lanka	Sr
Denmark	De	Surinam	Su
Egypt	Eg	Sweden	Swe
Finland	Fi	Switzerland	Swi
France	Fr	Syria	Sy
Germany, F. R.	Ge	Taiwan	Ta
Greece	Gr	Turkey	Tu
India	In	U.K.	UK
Ireland	Ir	U.S.A.	USA
Israel	Is	Venezuela	Ve
Italy	It	Yugoslavia	Yu
Japan	Ja		
Libya	Li		
Mauritius	Ma		
Mexico	Me		
Netherlands	Ne		
New Zealand	NZ		

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